A CLINICAL ECONOMICS WORKSTATION FOR RISK-ADJUSTED HEALTH CARE COST MANAGEMENT

Eric L. Eisenstein, D.B.A., Outcomes Research and Assessment Group
Joseph W. Hales, Ph.D., Division of Medical Informatics
Duke University Medical Center

ABSTRACT

This paper describes a healthcare cost accounting system which is under development at Duke University Medical Center. Our approach differs from current practice in that this system will dynamically adjust its resource usage estimates to compensate for variations in patient risk levels. This adjustment is made possible by introducing a new cost accounting concept, Risk-Adjusted Quantity (RQ). RQ divides case-level resource usage variances into their risk-based component (resource consumption differences attributable to differences in patient risk levels) and their non-risk-based component (resource consumption differences which cannot be attributed to differences in patient risk levels). Because patient risk level is a factor in estimating resource usage, this system is able to simultaneously address the financial and quality dimensions of case cost management. In effect, cost-effectiveness analysis is incorporated into health care cost management.[1]

INTRODUCTION

Cost Accounting

The continuing pattern of price increases has forced the health care industry to more closely examine its practices. As a result, health care providers are implementing cost accounting systems to better measure and manage their costs.[2, 3] While these systems have drawn on cost accounting principles and practices from other industries, their implementers have often made simplifying assumptions which distort product cost estimates. One of the more significant of these assumptions concerns the definition of end products.

Cost accounting systems allocate component costs to cost objects and end products are the most general form of cost object. Because of the potentially large number of health care end products, most organizations implementing health care cost accounting systems choose to group similar end products into product lines which are frequently called diagnosis groups. While there is no conceptual problem with this approach, problems do arise when these product lines are subsequently treated as if they were unique end products.

When health care administrators talk about a diagnosis group's average cost, average length of stay, or average resource usage, they are making product line statements. These statements are equivalent to talking about the average amount of labor in a Ford Escort automobile (any model). Attempting to define an average set of resources for a diagnosis group can be more problematic than attempting to define an average set of resources for all models in the Ford Escort product line. Just as there are different resource sets for sedans and stations wagons, there also may be different resource sets for different end products within a single medical diagnosis groups. Some of the differences in resource sets are caused by patient risk factors, comorbidities and complications. Other differences are traceable to differences in physician practice patterns.

As a clinical example, Diagnosis Related Group (DRG) 106 is defined as a coronary artery bypass surgery with one artery. Clinical researchers have long known that ejection fraction, patient age, and number of diseased vessels are important predictors of outcome in coronary artery disease.[4] And, recent research has shown that age above 60 years and ejection fraction lower than 50 points are both related to cost variances in these patients.[5] Nonetheless, traditional health care cost accounting practice would assign all patients in DRG 106 to the same end product and would not make adjustments in case-level resource usage estimates for variances in patient ejection fraction or age.

Failing to distinguish health care products based upon differences in patient risk means that the efficiency of practitioners who treat high risk patients in DRG 106 (with higher average costs) and those who treat low risk patients (with lower average costs) are all judged by the same standard resource set. This practice results in a cross-subsidy such that some cases in DRG 106 are over costed while other cases are under

0195–4210/95/$5.00 © 1995 AMIA, Inc.

costed. In fact, when health care cost accounting systems use product line level standard cost estimates, they will tend to over cost low risk cases and under cost high risk cases. Thus, low risk cases are subsidized and high risk cases are penalized. Risk-adjustment offers a possible solution to this problem.

Risk-adjustment is a commonly accepted technique in health care outcomes studies.[6] However, it has not been adopted by health care cost accountants as a means for adjusting their case cost estimates to account for significant resource consumption differences between patients. The next section will describe an interactive cost accounting system which is under development at Duke University Medical Center. We call this system the Clinical Economics Workstation. This workstation will incorporate risk-adjustments into its standard cost estimates.

Clinical Economics Workstation

Most health care cost accounting systems have limited capabilities for analyzing and modeling cost relationships. Two assumptions which limit the use of these systems for health care cost management are that: (1) linear relationships can adequately describe all cost behaviors and (2) activity-driven relationships (those related to case volume) are the only important relationships in modeling cost behavior. Because of these assumptions, health care cost accounting systems do not consider potentially important non-linear relationships in their models and they do not consider patient risk-level as a factor in their cost estimates.

Clinical workstations provide a natural vehicle for integrating patient clinical and financial information and for supporting the types of analysis and modeling required to include patient risk-levels in cost accounting calculations. Medical informatics researchers have already demonstrated the benefits of combining data-analytic and decision-making tasks in the same workstation[7] and they have developed tools to assist users in the creation of predictive/diagnostic models from patient databases.[8] However, these workstations have not typically included patient financial information in their data bases.[9]

The Clinical Economics Workstation will provide cost analysis and management functions which are not included in clinical workstations. And, it will use clinical data to risk-adjust expected resource usage. Using clinical data for risk-adjustment is an important feature as previous studies have shown that billing (claims) data lacks important diagnostic and prognostic information for making risk adjustments in outcomes studies.[10] All clinical information for this workstation will come from the Duke Cardiovascular Disease Data Bank[11] and patient hospital charge information will come from the Duke Hospital Information System. Patient hospital charges will be converted to hospital costs prior to modeling using the cost-to-charge ratios and per diems derived from Duke University Medical Center's annual Medicare Cost Report.[12]

The initial implementation of the Clinical Economics Workstation will support two functions: (1) Cost-Driver Analysis and (2) Case Cost Modeling. The Cost-Driver Analysis functions will assist a user in defining relationships between clinical indicators and specific case resources. These relationships will then be used to risk-adjust the estimated consumption of those resources on individual cases. The Case Cost Modeling functions will assist the user in testing these relationships. It will also be able to present the researcher with cases which are clinically similar to those under assessment. This presentation of similar cases will allow users to better assess the functioning of their risk-adjusted cost accounting models. Additionally, the workstation's Case Cost Modeling function will also process actual clinical and billing data in batch mode and produce variance analysis reports which critique resource utilizations.

RISK-ADJUSTED COST MANAGEMENT

Health Care Variance Analysis Model

Variance analysis is concerned with determining the reasons for differences between expected and actual cost accounting values. By convention, expected values are called standard values. At the resource level, variance analysis seeks to determine the reasons for differences between standard unit prices expected (SP) and actual unit prices paid (AP) and between the standard quantity expected for an end product (SQ) and the actual quantity consumed (AQ) in producing a particular end product. The difference between AP and SP is called the Price Element and the difference between AQ and SQ is called the Usage Element. When AQ is less than SQ there is a Positive Usage Variance and when AQ is greater than SQ there is a Negative Usage Variance.

Current health care cost accounting practice attributes all Usage Variances between patients within a single diagnostic group to differences in efficiency. In contrast, our approach is to divide Usage Variances into their risk-based components (resource consumption differences attributable to different patient risk levels) and their non-risk-based components (resource consumption differences which cannot be attributed to differences in patient risk levels). By separating Usage Variances into these two components, the responsibility for those resource consumption decisions which practitioners can control is separated from those resource consumption decisions which are caused by differences in patient risk levels and which are not controllable by practitioners.

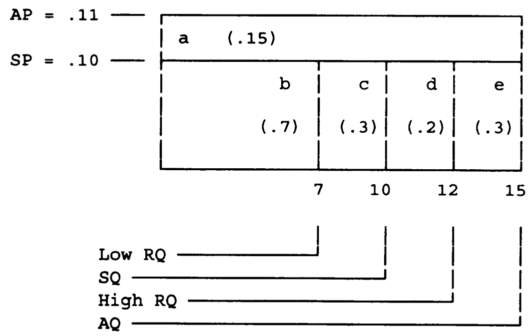
```
HEALTH CARE VARIANCE ANALYSIS MODEL
____________________________________________________________

AP x AQ        SP x AQ        SP x RQ        SP x SQ
  |              | |            | |              |
  |______________| |____________| |______________|

  Price Element    Non-Risk         Risk
                   Element          Adjustment

                   |_______________________________|

                         Usage Element
  |________________________________________________|

              Total Variance

Usage Element     = Non-Risk Element
                    + Risk Adjustment
Non-Risk Element = (SP x AQ) - (SP x RQ)
Risk Adjustment  = (SP x RQ) - (SP x SQ)

Where:
  Risk-Adjusted Quantity (RQ): the estimated
     units of a resource to be used in an end
     product, after adjusting for the patient's
     severity level.
```

Figure 1: Variance Components

Figure 1 outlines the Health Care Variance Analysis Model which is the conceptual basis for the Clinical Economics Workstation. This model is similar to the acuity variance model developed by Finkler.[13] Both models divide the Usage Element into two components. In our model, this division is made possible by introducing a new term, Risk-Adjusted Quantity (RQ), into health care cost accounting theory. Risk Adjustment is the difference between the Risk-Adjusted Quantity and the Standard Quantity and it is the amount by which the Standard Quantity must be adjusted to account for the patient's risk level. The Non-Risk Element is the difference between the Actual Quantity and the Risk-Adjusted Quantity. The Non-Risk Element is the true efficiency variance, after adjusting for the patient's risk level.

Figure 2 depicts key relationships in the Health Care Variance Analysis Model. In this diagram, the vertical axis measures unit prices of Lanoxin and the horizontal axis measures quantities used a case. The area of the entire rectangle represents Actual Cost (AP x AQ), area a is the Price Element (AQ x (AP - SP)), and areas b and c represent Standard Cost (SP x SQ). When RQ is less than SQ (Low RQ), area c represents the Risk-Adjustment and areas d and e are the Non-Risk Element. Conversely, if RQ is greater than SQ (High RQ), area d is the Risk-Adjustment and area e is the Non-Risk Element. The different values for Usage Element components are shown in the example in the bottom portion of Figure 2.

RISK-ADJUSTED COST RELATIONSHIPS FOR LANOXIN



Risk Adjustment Example:

	Risk Adjustment	Non-Risk Element	Usage Element
Low RQ	-0.3	0.8	0.5
Average RQ	0.0	0.5	0.5
High RQ	0.2	0.3	0.5

Figure 2: Rectangles represent cost components. Their areas are proportional to their contribution to total cost (AP x AQ).

Across all patient risk levels, RQ is the only variance measurement that changes. The four remaining measurements from traditional cost accounting theory (AP, AQ, SP, and SQ) are constant. This adjustment in RQ is needed because a systematic biasing occurs in traditional health care cost accounting Usage Element computations. Specifically, when RQ is greater than SQ (High RQ), the Usage Element is over valued and Standard Costs are under valued, and when the RQ is less than SQ (Low RQ), the Usage Element is under valued and Standard Costs are over valued. In this manner, a traditional health care cost accounting system systematically penalizes higher risk cases and rewards lower risk cases.

Clinical Cost-Driver Analysis

Traditional cost accounting theory separates all costs into fixed and variable components for modeling. Variable costs change in direct proportion to changes in activity level and fixed costs remain constant within a specific range of activity. While health care cost accounting has adopted this distinction, other explanations for variations, such as patient severity of illness, which are unique to the health care industry are not considered in cost modeling. Dudley et al.[5] and Smith et al.[14] demonstrated that general health measures and specific measures of clinical severity effect clinical outcomes as well as the cost of treating patients. Within this context, patient risk factors appear to function as cost drivers.[15] However, unlike traditional cost drivers, patient risk factors are related to changes in patient risk levels instead of changes in overall activity levels. Thus, implementing a cost accounting system which includes patient risk factors as cost drivers has potential for increasing the overall accuracy of standard cost estimates.

Previous researchers have suggested that clinical databases can be technologies for health care decision making.[16] The prototype Clinical Economics Workstation will assess the potential for using patient risk information from clinical data bases as cost drivers in a risk-adjusted cost management system for coronary artery bypass surgery. If the initial results from this prototype are successful, other cardiovascular disease diagnosis groups will be modeled.

Candidate clinical cost drivers for coronary artery bypass surgery will be identified through three steps. First, the relevant literature will be reviewed to determine which clinical indicators have been associated with variations in patient risk levels for coronary artery bypass surgery. It will be assumed that those clinical indicators which effect patient risk levels will also have a similar effect upon patient charges.

In the second step, the Clinical Economics Workstation will use Cox proportional hazards models and artificial neural networks, ANNs, to determine the relative abilities of clinical indicators to predict total patient costs. Although ANNs have been used in clinical cardiology[17] and in financial[18] applications, they have not previously been used to model patient care costs. The ability of ANNs to model non-linear relationships makes them logical choices for modeling the types of data that will be used in this study. In both the Cox and the ANN models, total patient costs will be the dependent variable and the clinical indicators will be the independent variables. Those clinical indicators which are strongly associated with variations in total patient costs will be termed clinical cost drivers.

The third step will use the case-level cost drivers which were identified in the second step to model resource utilization. In this step, the Clinical Economics Workstation will create a second set of Cox and ANN models to determine the relationships between case-level cost drivers and each of the resources used in coronary artery bypass surgery cases. In these models, resource consumption will be the dependent variable and case-level cost drivers will be the independent variables. The objective of these models will be to identify the mechanisms whereby clinical factors change the consumption of specific resources. Once these resource-level models are created, they will provide a mechanism for dynamically determining the Risk-Adjusted Quantity (RQ) which is required for different configurations of patient risk factors. As a final test, the individual resource consumption models will be used to estimate total patient hospital charges and the accuracy of these models will be compared with that of the case-level models (step 2) and of traditional health care cost accounting (no risk adjustment) practices.

CONCLUSION

This paper has introduced the Clinical Economics Workstation and has presented its major conceptual foundation, the Health Care Variance Analysis Model. We believe that this workstation, because it risk-adjusts its resource consumption estimates and uses clinical data to identify cost drivers, represents a significant advance over existing health care cost accounting technologies. We believe that in an era of capitated pricing this technology will be especially useful for healthcare administrators by assisting them in estimating the true costs of care for specific patient populations.

ACKNOWLEDGMENT

This investigation was supported in part by National Research Service Award F32 HS00090-01 from the Agency for Health Care Policy and Research.

REFERENCES

1. Eisenberg JM. Clinical economics: a guide to the economic analysis of clinical practices. *JAMA*. 1989;262(20):2879-2886.

2. Rotch W. Activity-based costing in service industries. *Cost Management*. 1990 Summer: 4- 14.

3. Carr LP. Unbundling the cost of hospitalization. *Management Accounting*. 1993 Nov:43-48.

4. Harris PJ, Harrell FE, Lee KL, Behar VS, Rosati RA. Survival in medically treated coronary artery disease. *Circulation* 1979;60:1259-1269.

5. Dudley RA, Harrell FE, Smith LR, Mark DB, Califf RM, Pryor DB, Glower D, Lipscomb J, Hlatky M. Comparison of analytical models for estimating the effect of clinical factors on the cost of coronary artery bypass graft surgery. *Journal of Clinical Epidemiology*. 1993;46(3):261-271.

6. Iezzoni LI. *Risk Adjustment for Measuring Health Care Outcomes*. Ann Arbor, MI: Health Administration Press; 1994.

7. Lehmann HP, Shortliffe EH. Thomas: building Bayesian statistical expert systems to aid in clinical decision making. *Computer Methods & Programs in Biomedicine*. 1991 Aug;35(4):251-260.

8. Aliferis C, Chao E, Cooper GF. Data Explorer: a prototype expert system for statistical analysis. *Proceedings of the Seventeenth Annual Symposium on Computer Applications In Medical Care*. MacGraw-Hill, Inc. 1993:389-393.

9. Hammond JE, Berger RG, Carey TS, Fakhry M, Rutledge R, Kichak JP, Cleveland TJ, Dempsey MJ, Tsongalis NM, Ayscue CF. Progress report on the clinical workstation and clinical data repository at UNC Hospitals. *Proceedings of the Seventeenth Annual Symposium on Computer Applications In Medical Care*. McGraw-Hill, Inc. 1993:243-247.

10. Jollis JG, Ancukiewicz M, DeLong ER, Pryor DB, Muhlbaier LH, and Mark DB. Discordance of databases designed for claims payment versus clinical information systems. *Ann Intern Med*. 1993;119:844-850.

11. Califf RM, Harrell FE, Lee KL, Rankin JS, Hlatky MA, Mark DB, Jones RH, Muhlbaier LH, Oldham HN, Pryor DB. The evolution of medical and surgical therapy for coronary artery disease: A 15-year perspective. *JAMA*. 1989;261:2077-2086.

12. Mark DB. Medical economics and health policy issues for interventional cardiology. In: Topol EJ, ed. *Textbook of Interventional Cardiology*. 2nd ed. Philadelphia: W.B. Saunders, 1993:1323-1353.

13. Finkler SA. *Essentials Of Cost Accounting For Health Care Organizations*. Gaithersburg, MD: Aspen Publishers, Inc.; 1994.

14. Smith LR, Carmelo AM, Molter BS, Elbeery JR, Sabiston DC, Smith PK. Preoperative determinants of postoperative costs associated with coronary artery bypass graft surgery. *Circulation*. 1994(5 Pt 2):II124-II128.

15. Raffish N, Turney PBB. Glossary of activity-based management. *Cost Management*. 1991;Fall:53-63.

16. Pryor DB, Lee KL. Methods for the analysis and assessment of clinical databases: the clinician's perspective. *Statistics In Medicine*. 1991;10:617-628.

17. Baxt WG. Analysis of the clinical variables driving decisions in an artificial neural network trained to identify the presence of myocardial infarction. *Annals of Emergency Medicine*. 1992;21(12):35-40.

18. Widrow B, Rumelhart DE, Lehr MA, Neural networks: applications in industry, business, and science. *Communications Of The ACM*. 1994 March;37(3):93-105.